National Aeronautics and Space Administration

Unmanned Aerial Systems Traffic Management (UTM)

SAFELY ENABLING UAS OPERATIONS IN LOW-ALTITUDE AIRSPACE

NASA

http://www.utm.arc.nasa.gov

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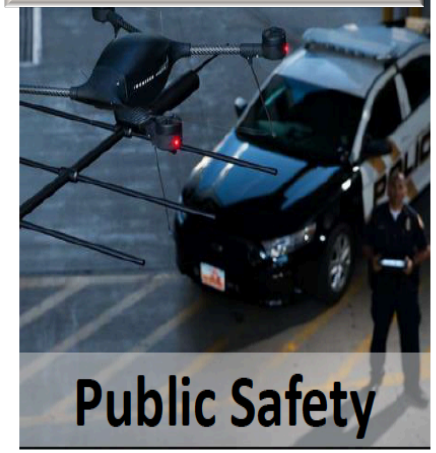
Applications of Unmanned Aerial Systems

Aerial Instruments

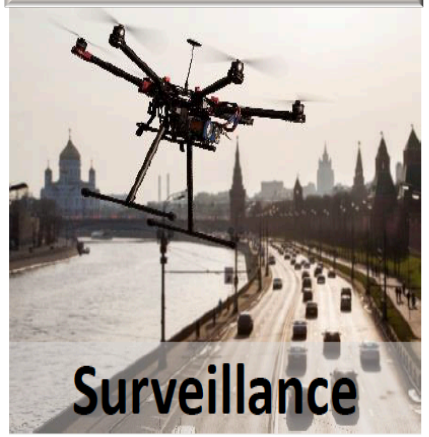


Public Safety

Cargo

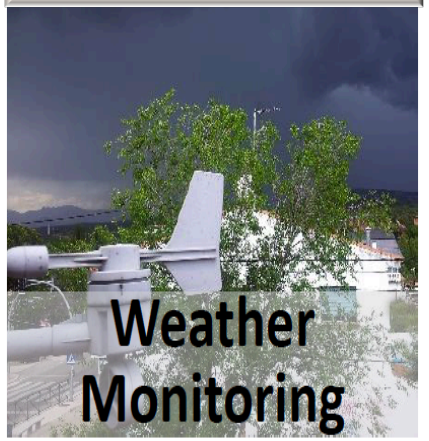
Deliveries

Aerial Instruments



Surveillance

Aerial Instruments



Weather Monitoring

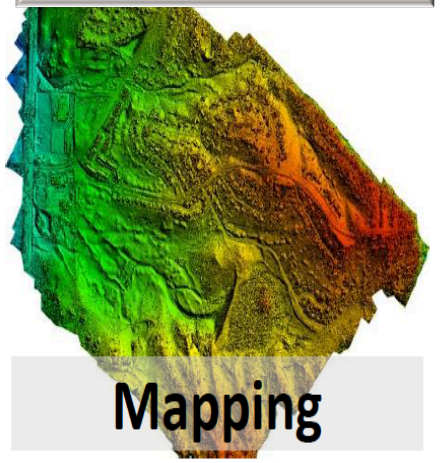
Aerial Instruments

News Gathering

Aerial Instruments

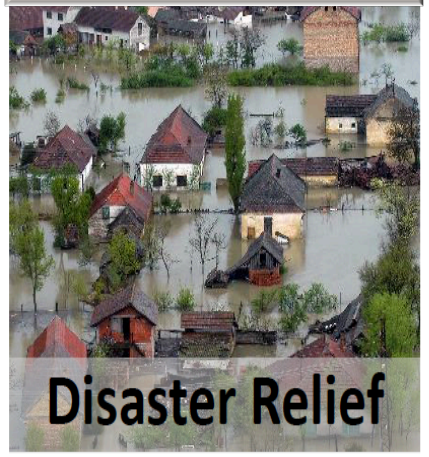
Agriculture

Aerial Instruments



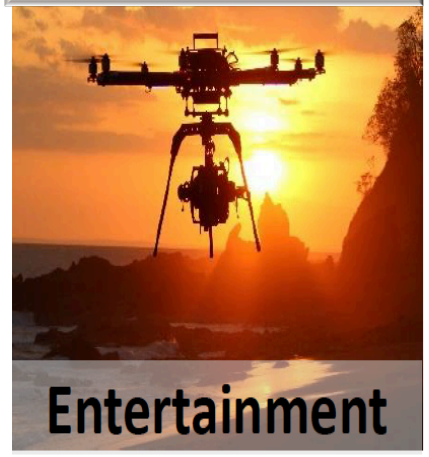
Mapping

Aerial Instruments



Disaster Relief

Aerial Instruments



Entertainment

Aerial Dispersal

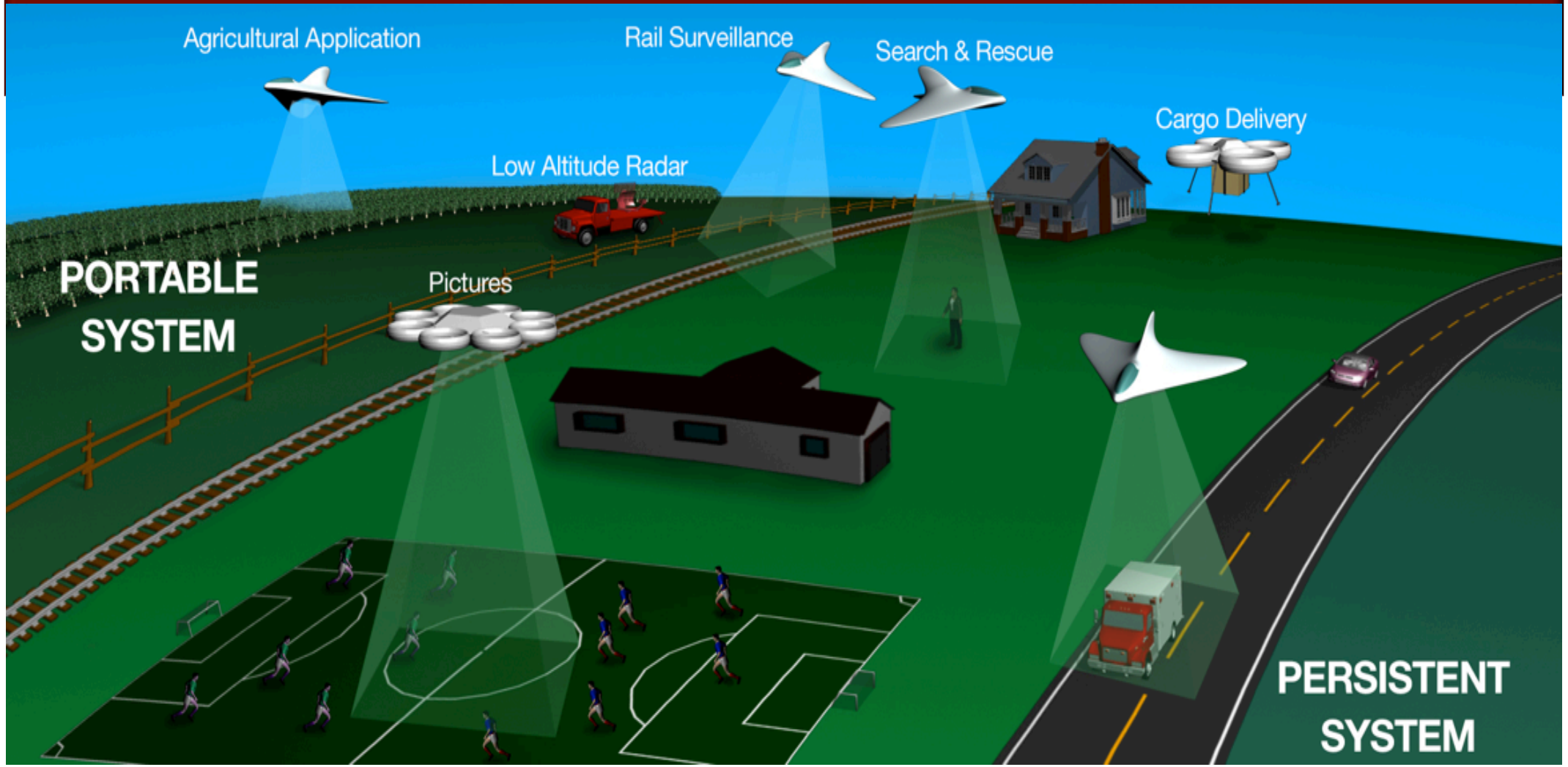
Spraying/Seeding

Stages of Traffic Management: Requirements are Different

http://www.kcet.org/updaily/socal_focus/history/la-as-subject/7th-and-broadway.html
1920, Photo Collection, Los Angeles Public Library

Low-Altitude Unmanned Aerial System Operations

Goal: Ensure safe and efficient operations



Balancing Multiple Needs

National and Regional Security

Protecting key assets

Safe Airspace Integration

Mantra 1: Flexibility where possible and structure where needed

Mantra 2: Risk based- Geographical needs, application, and performance-based airspace operations

Scalable Operations for Economic Growth

Ever-increasing applications of UAS: Commercial, Agricultural, and Personal

Low Altitude UAS operations

- Small UAS forecast – 7M total, 2.6M commercial by 2020
- Need a way to manage beyond visual line of sight UAS
- Vehicles are autonomous and airspace integration is necessary – particularly multiple operations in the same airsapce
- Operators want flexibility for operations
- Regulators need a way to put structures as needed
- Transition between uncontrolled and controlled operations
- Safety of manned and unmanned operations is critical

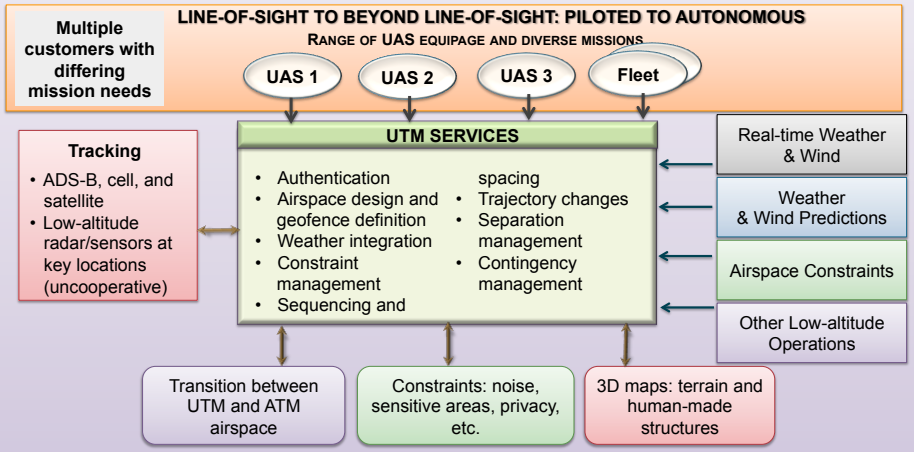
What is UAS Traffic Management (UTM)?

Research Platform that

- Gives situational awareness of all airspace constraints and info about other operations to UAS operators, support service suppliers, and regulators
- Allows to exchange data among UAS operators as well as regulator
- Allows UAS operators to submit flight plans to execute a specific mission in low-altitude airspace, and
- Determines how to safely enable such single or multiple UAS operations either within visual line of sight or beyond visual line of sight
- Integrates airspace and vehicle operations

Product: Validated airspace operations requirements: roles/responsibilities; federated, networked, and interoperable data exchange; information architecture; and air/ground integrated concept of operation

- Airspace configuration (static and dynamic geo-fencing)
- Weather and wind (actual and predicted)
- Demand/capacity imbalance management
- 3D maps
- Track and locate (cell, ADS-B, satellite, psudo-lites)
- Conflict (V2V, sense and avoid) and hazard avoidance
- Last and first 50 feet operation
- Contingency management



Value Proposition of UTM

(Agreed upon by stakeholders and FAA as discussed at OSTP panel)

- Unmanned vehicle operations coordination through agreed upon data/ information exchanges about each others operations and with FAA systems
- Exceptions handling – entry into controlled airspace
- Beyond Part 107 operations– 450 feet
- Beyond visual light of sight
- Manned and unmanned vehicle operations coordination
- Higher density operations

- Longer-term: Changing the paradigm of airspace operations

UTM Research Goals and Characteristics

- Conduct research, development and testing to identify airspace operations requirements to enable large-scale visual and beyond visual line of sight UAS operations in the low-altitude airspace
- Use build-a-little-test-a-little strategy – remote areas to urban areas
  - Low density: No traffic management required but understanding of airspace constraints
  - Cooperative traffic management – Understanding of airspace constraints and other operations
  - Manned and unmanned traffic management – Scalable and heterogeneous operations
- UTM construct consistent with FAA's risk-based strategy
- UTM research platform is used for simulations and tests
- UTM offers path towards scalability

Principles and Services for Safe Integration

- Principles
  - Authenticated users and UAS are allowed to operate in the airspace
  - UAS stay clear of each other
  - UAS and manned aircraft stay clear of each other
  - UAS operator has complete awareness of airspace and other constraints and stay clear of them
  - Public safety UAS have priority over other UAS

- Key UAS related services
  - Authentication
  - Airspace configuration and static and dynamic geo-fence definitions
  - Weather and wind prediction and sensing
  - Conflict avoidance (e.g., airspace notification, V2V)
  - Demand/capacity management
  - Large-scale contingency management – GPS outage, cell outage, etc.

- Research platform is cloud-based

- UTM research identifies roles and responsibilities of operator, air navigation service provider, and UAS support service providers

Defining UAS Operator and ANSP/UTM Roles

UAS Operator

- Work with Original equipment manufacturer
- Communication, Navigation, and Surveillance (CNS)
- Register
- Train/qualify to operate
- Avoid other aircraft, terrain and obstacles
- Respect airspace constraints
- Avoid incompatible weather

Through

- Performance-based regulation where practical
- Limited categories of operator types, matched to regulations

Third-party entities may provide support services but are not separately categorized or regulated.

Air Navigation Service Provider (ANSP)

→ ***UAS Traffic Management (UTM)***

- Define airspace constraints
- Foster collaboration among UAS operators to deconflict their operations
- Where demand warrants, provide air traffic control

Through

- Near real-time airspace control
- Where it is needed, air traffic control integrated with manned aircraft traffic control

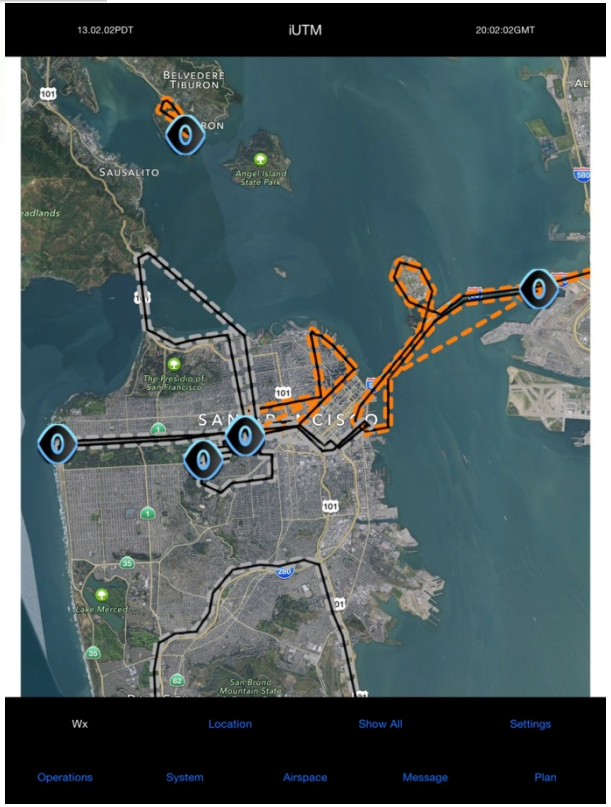
UAS Operator/UTM Functions

UTM: AIRSPACE MANAGEMENT

- Notifications accessible to UAS operators and public
- Static (like TFR) and dynamic (like security or public health scenario)

UAS OPERATOR

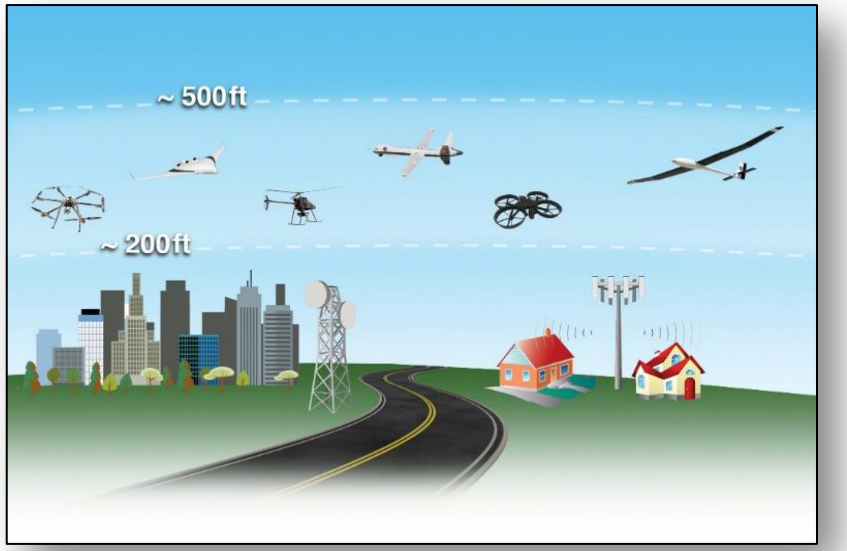
- Broadcast identity (and possibly intent)
- Operations accessible by all
- No anonymous flying



UAS Operator/UTM Functions

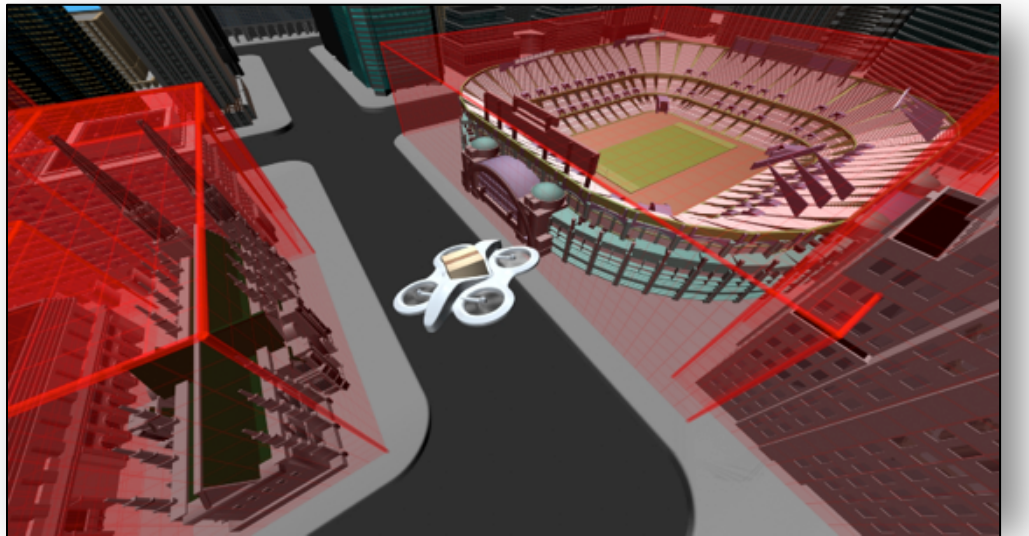
UTM Example Airspace Management

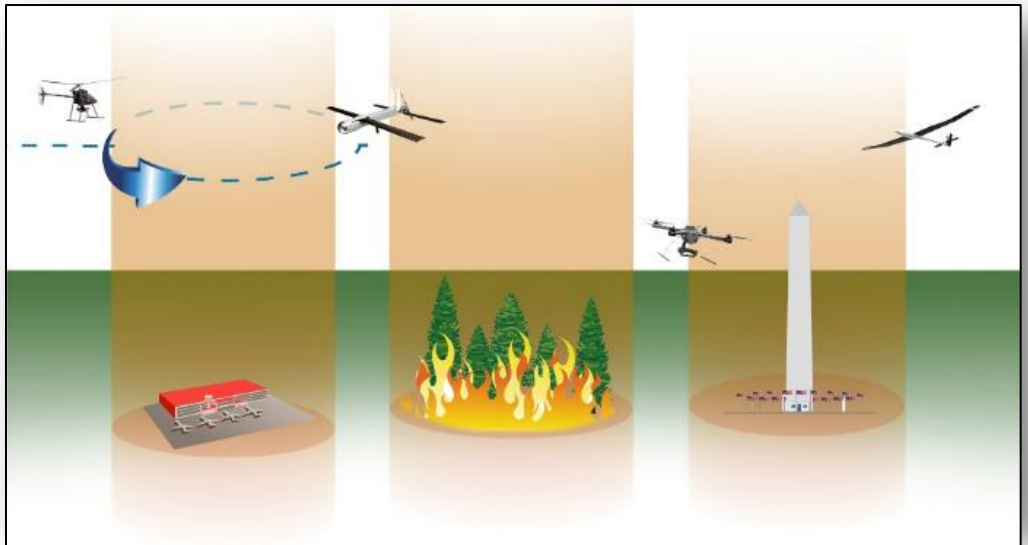
- Consider other traffic and underlying environment
- Can be keep-out or keep-in requirement
- May be static or dynamic (near-real time)



UAS Operator:

- Operator can comply through geofences or operational control

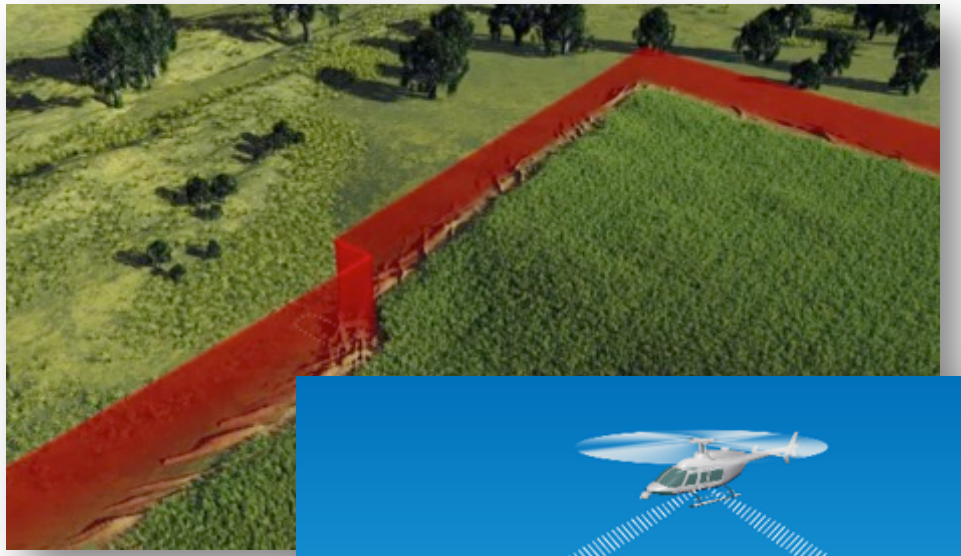


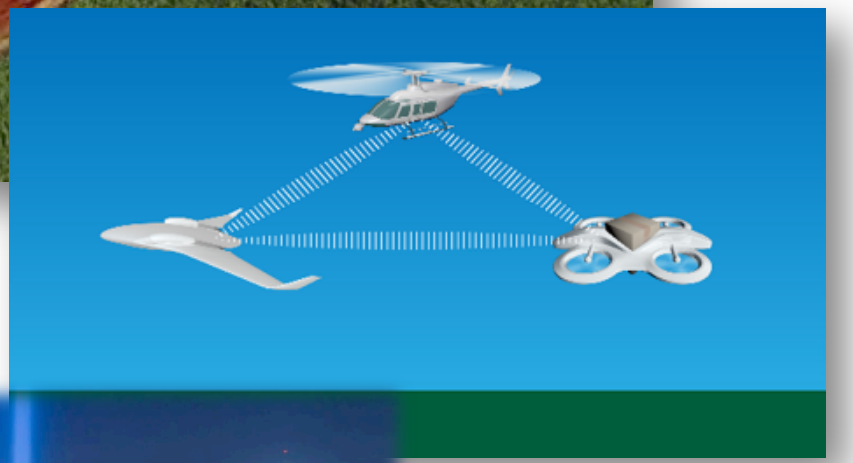


UAS Operator/UTM Functions

UAS Operator: Traffic Avoidance

- Detect Sense And Avoid (DSAA) to manned aircraft predicated on right of way
- Status and intent exchange in accordance with standards
- Collaborative decision making
- Contingency planning and response (system outages, unreported weather, etc.)





UTM: Enable Collaborative Exchange

- Standards for publish and access
- If needed, provision of data repository

UTM Functions

Route Structure

- Only where needed for safety or efficiency of flight
- Procedural rules-of-road (corridors, altitudes, etc).

Flow Control

- Only where needed for safety or efficiency of flight
- Manage access into areas of operation, not particular operation

Air Traffic Control

- Integrated with manned air traffic control, where positive UAS control is required for safety or efficiency of flight
- Static or dynamic application (e.g., ability to respond in crisis situation where sustained mixed operations are required)

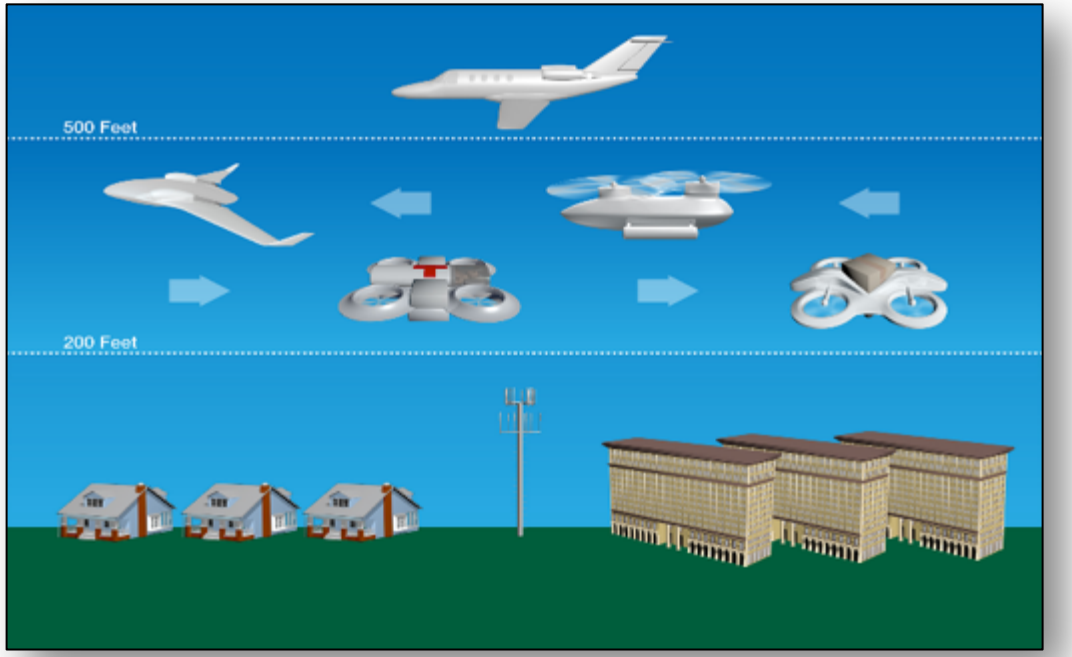
Mantra 1:
Flexibility where possible and structure where needed

Mantra 2:
Risk based- Geographical needs, application, and performance-based airspace operations

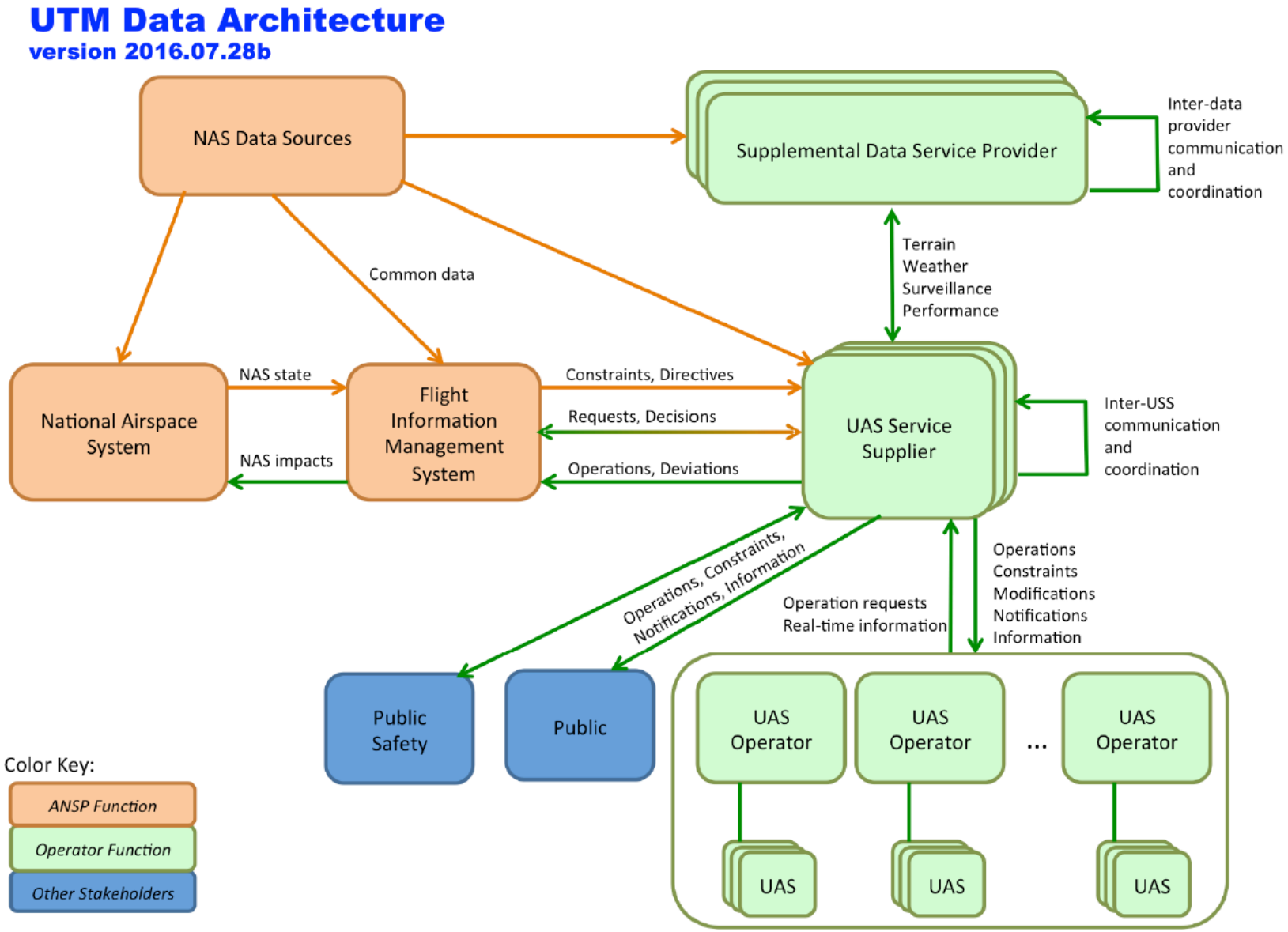
Supporting Functions

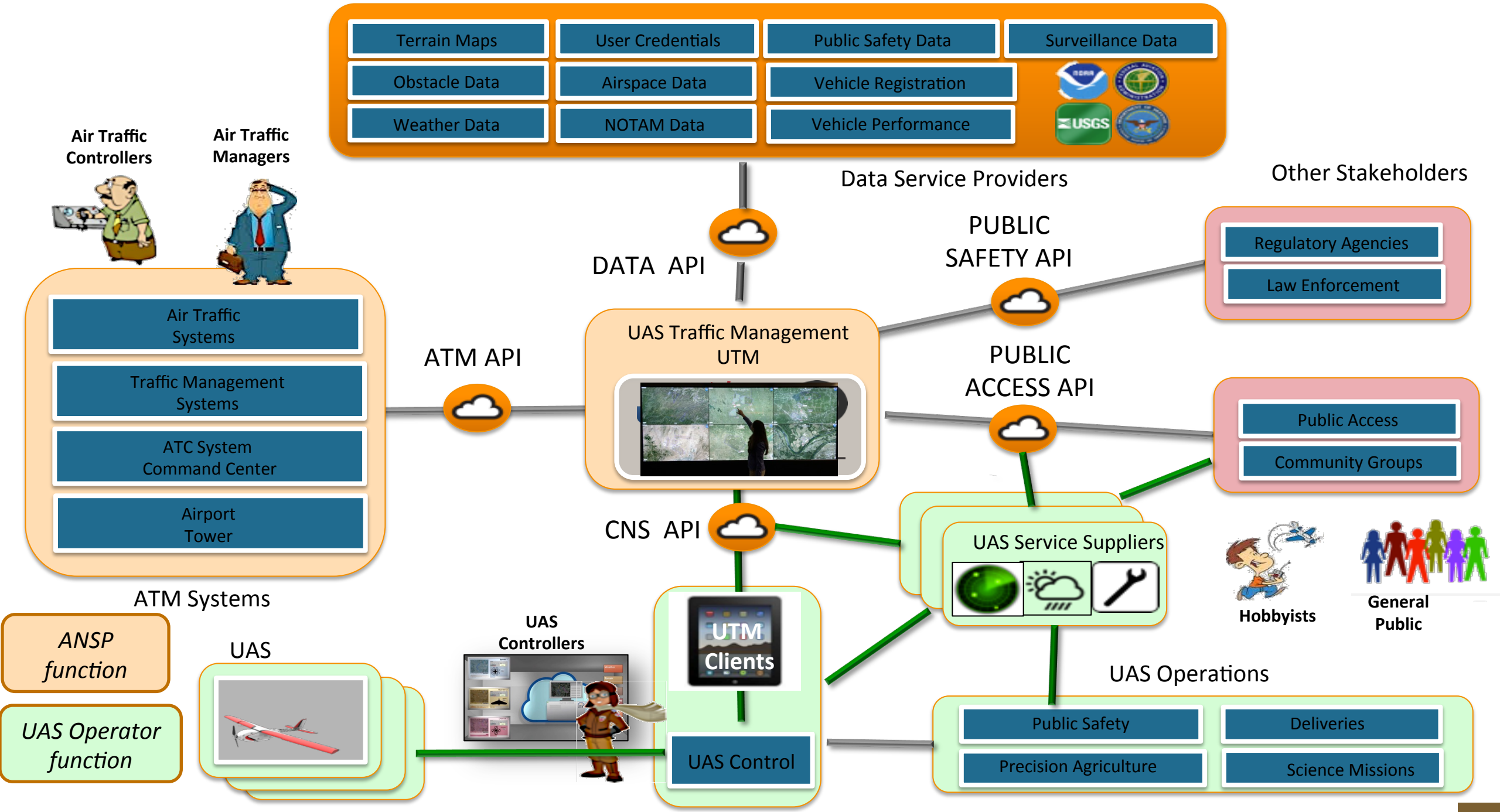
Wind & Weather Integration

- Operator responsibility, may be provided by third party
- Actual and predicted winds/weather
- No unique approval required



Architecture




Terrain Maps
User Credentials
Public Safety Data
Surveillance Data
Obstacle Data
Airspace Data
Vehicle Registration
Weather Data
NOTAM Data
Vehicle Performance
USGS
Data Service Providers
Other Stakeholders
Air Traffic Controllers
Air Traffic Managers
DATA API
PUBLIC SAFETY API
Regulatory Agencies
Law Enforcement
Air Traffic Systems
Traffic Management Systems
ATC System Command Center
Airport Tower
ATM API
UAS Traffic Management UTM
PUBLIC ACCESS API
Public Access
Community Groups
ATM Systems
CNS API
UAS Service Suppliers
Hobbyists
General Public
ANSP function
UAS Operator function
UAS
UAS Controllers
UTM Clients
UAS Control
UAS Operations
Public Safety
Deliveries
Precision Agriculture
Science Missions

Information Flow

Vehicle Performance Database

UTM Vehicles Registration

Check if UVIN is registered

2

Schedule delivery to …

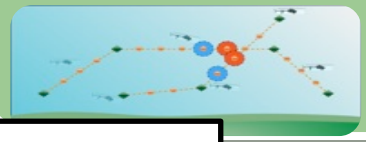
Operator submits operation (waypoints; vehicle info; operator data)

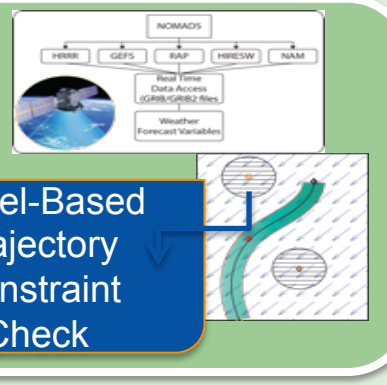
1

Check static constraints

3

Dynamic Constraints
- Weather
- Conflict Detection
- Feasibility





Model-Based Trajectory Constraint Check

Check dynamic constraints

4

UAS Support Services

5

Share information

UAS Traffic Management UTM

6

Contingency Management
- Geo-fence breach
- Loss of C2
- Emergency responder

7

Operation completed

UAS Operator function

ANSP function

UTM Research Technical Capability Level

Each capability is targeted to type of application, geographical area and uses risk-based approach

CAPABILITY 1

- Reservation of airspace volume
- Over unpopulated land or water
- Minimal general aviation traffic in area
- Contingencies handled by UAS pilot
- Enable agriculture, firefighting, infrastructure monitoring

CAPABILITY 2

- Beyond visual line-of-sight
- Tracking and low density operations
- Sparsely populated areas
- Procedures and “rules-of-the road”
- Longer range applications

CAPABILITY 3

- Beyond visual line of sight
- Over moderately populated land
- Some interaction with manned aircraft
- Tracking, V2V, V2UTM and internet connected
- Public safety, limited package delivery

CAPABILITY 4

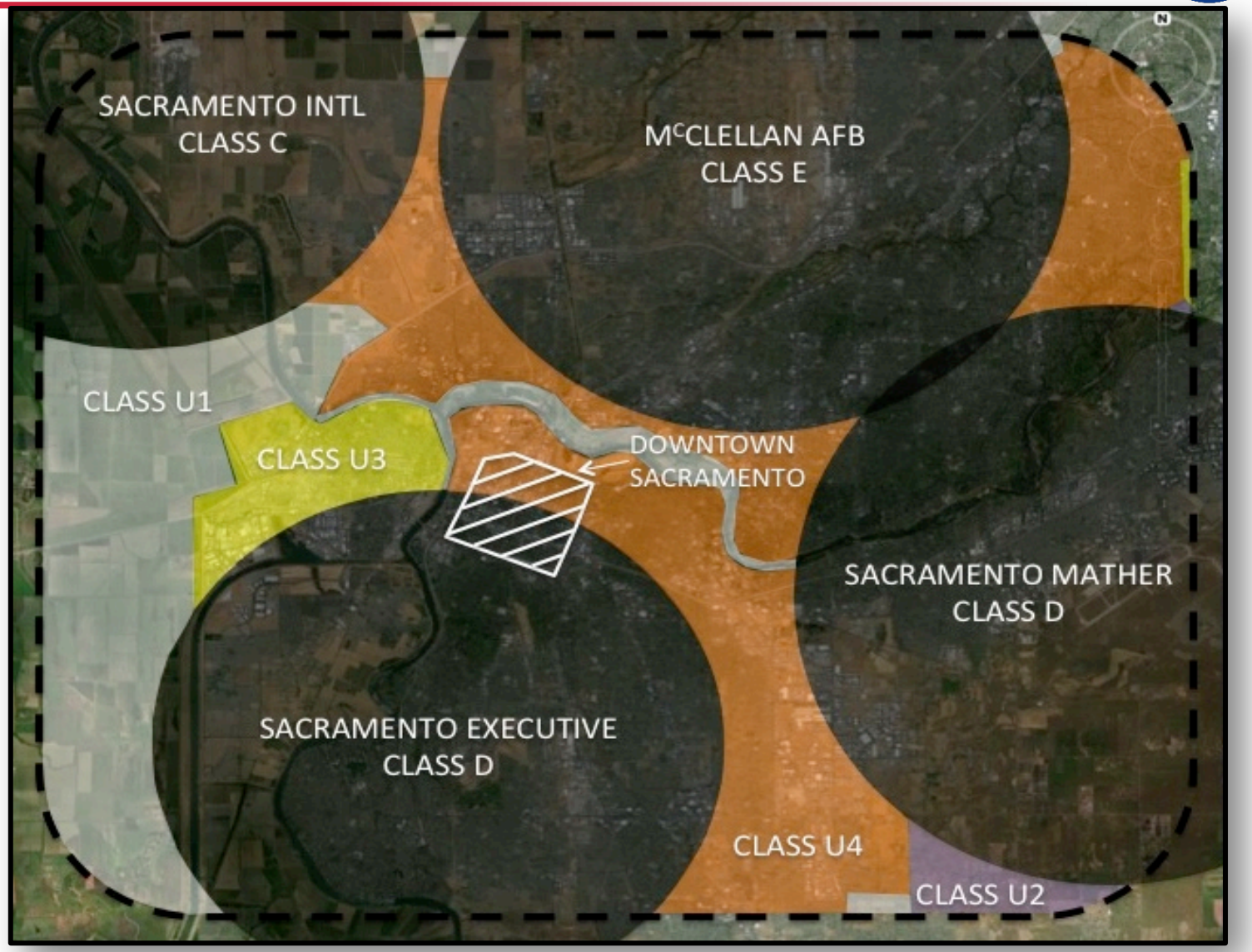
- Beyond visual line of sight
- Urban environments, higher density
- Autonomous V2V, internet connected
- Large-scale contingencies mitigation
- News gathering, deliveries, personal use

Notional UTM Airspace

Multiple providers could offer some UTM services

Tailoring operational services based on geographical area needs

Vehicle performance could be different



Potential Users of UTM

Air Traffic Controllers

Hobbyists

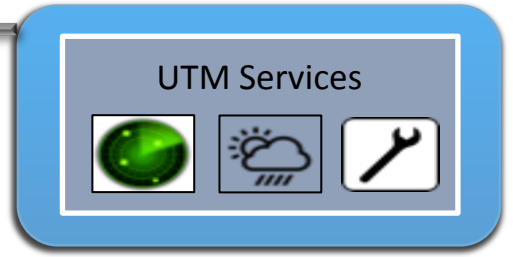
Manned Aircraft Pilot

General Public

UTM Manager

UAS Controllers

UAS Operators



Can use UTM information services for safety

Reviews UAS operations prior to take off, maintains situation awareness for safety

Can use UTM information services for safety, privacy, and security concerns

Makes strategic decisions to ensure safety, efficiency and equity of the UTM Airspace

Responsibly for the safe conduct of UAS vehicle(s)

Legal entity that requests access to UTM airspace and manages UAS operations

TCL 1 Demonstration

What: Demonstrated concept for management of airspace in lower risk environments and multiple UAS operations

Where: Crows Landing, CA

Who: NASA and several flying, weather, surveillance partners

When: Aug 2015

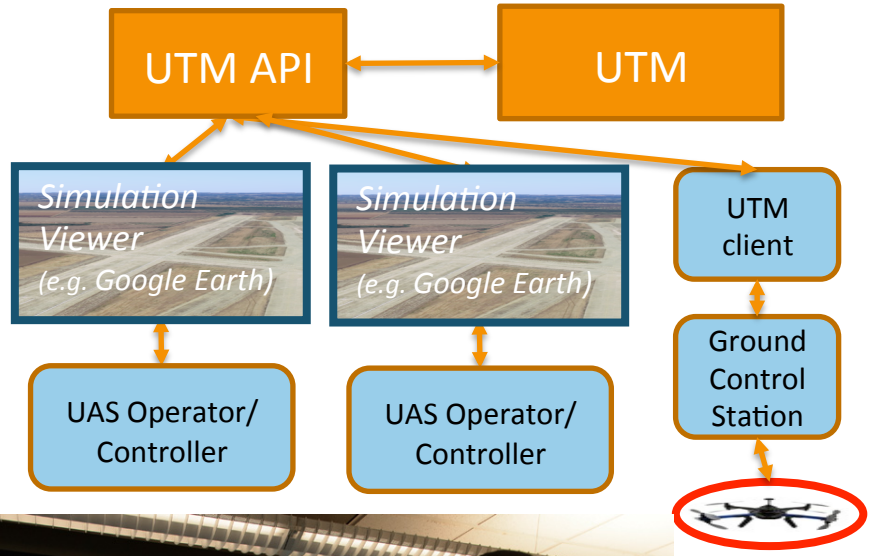
Collected state data for operations, weather conditions, communications with UTM System, sound readings

Built foundation for future demonstrations with proposed increased capabilities

Showed that operations that could represent many business cases are already enabled with the initial concept

NASA UTM Simulation Capabilities

- Validation and Verification of UTM research prototype functions
- Develop, demonstrate, and evaluate advanced UTM services and operations
- Develop tools and procedures to manage UTM ops
- Accelerate and increase value of field tests and provide live virtual constructive (LVC) environments
- Simulate complex operations that cannot be done in the field (e.g. urban ops, 911 type scenarios)



National Safe UAS Integration Campaign

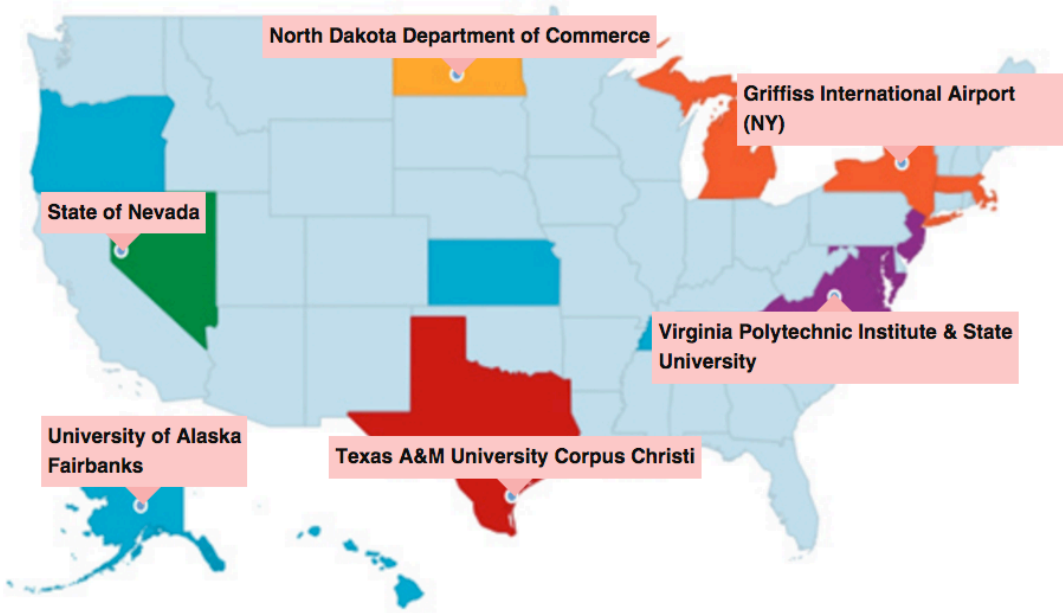
What: Demonstrated management of geographically diverse operations, 4 vehicles from each site flown simultaneously under UTM

Where: All 6 FAA UAS Test Sites

Who: NASA, Test Sites, support contractors

When: 19 April 2016

24 live vehicles, over 100 live plus simulated flights under UTM in one hour –Highly successful



Received positive feedback from the FAA Test Sites on the UTM concepts, technologies and operations

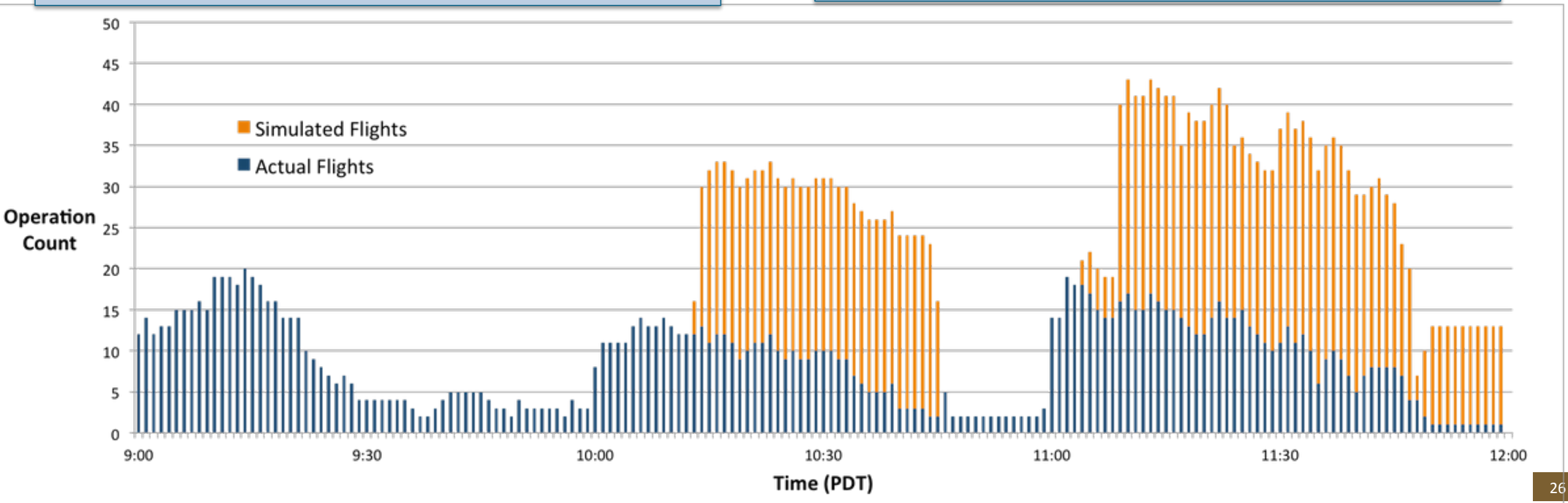
API based model worked well – enabled operator flexibility, exchanged information, and maintained safe operations

Safe UAS Integration National Campaign

National Campaign Statistics:

- 4 types of vehicles at each site
- 3 Hours
- 102 real, distinct flights

- 67 simulated operations injected
- About 31 hours of flight time
- 281.8 nmi flown



TCL 2 Demonstration

What: Extension of TCL 1 to BVLOS. Will exercise handling of off-nominal scenarios, altitude stratification, initial wx integration, surveillance data, and other services.

Where: Likely Reno-Stead, NV

Who: NASA and several flying, weather, surveillance partners

When: Oct 2016

Demonstrate efficient airspace use through multi-segmented plans, altitude stratification, and other procedures

Incorporate input from surveillance systems to share awareness with all stakeholders within UTM

Fly BVLOS with multiple vehicles procedurally separated supported by data from the UTM System

NASA-FAA RTT and Working Groups

- NASA and FAA have established an RTT
- FAA extension language – NASA and FAA to work together on a plan and UTM pilot project
- Working groups
  - Data definition
  - Information architecture
  - Concept of operations and use cases
  - Communications and spectrum (with FCC and FAA)
  - Weather (with NCAR, NOAA, and FAA)
  - Separation (sense and avoid and V2V)
  - Performance requirements

Vehicle Technology Challenges

- Low Size, Weight, Power, and cost – Sense and avoid
  - Detection of obstacles such as wires as well as other moving objects
- Tracking: Cell phone, ADS-B, Satellite
- Reliable control system
- Safe landing under failure
- Long endurance (45 min current battery life)
- Cyber secure/spoof free vehicles
- Graceful landing in case of failure with low kinetic energy – safe flying around people
- Ultra-low noise from vehicles
- Last/first 50 feet safe autonomous operation

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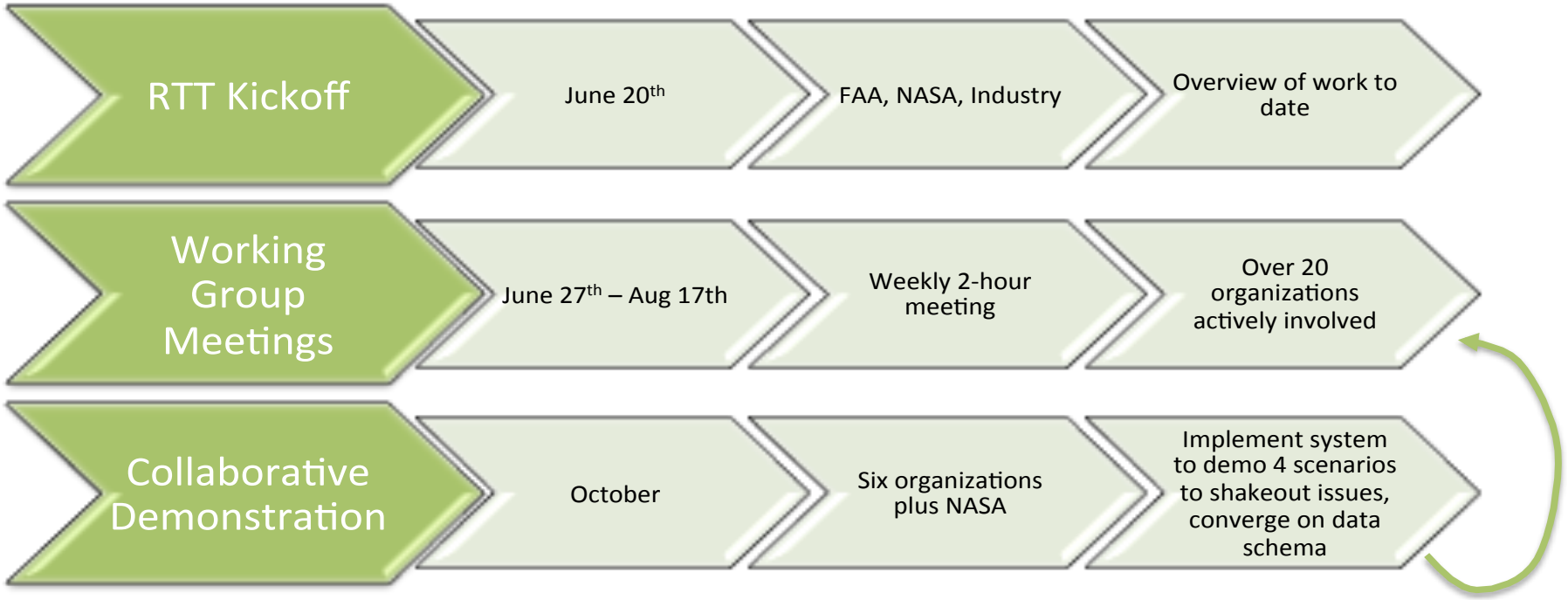
UTM Data Exchange Working Group

First NASA-FAA-Industry working group under the UTM Research Transition Team



Initial scenarios under development:

- Airspace configuration change
- Entry of sUAS into unauthorized airspace
- "All Land" scenario
- High density operations

UTM

- Supports:
  - Multiple UAS operations and FAA ATM interoperability
  - Exploring pathfinder use including security – verifying authorized/authenticated users
  - DOD use cases
    - MTR and SUA information exchange with UAS operator and vice-a-versa
    - Protecting key sites – UTM to verify authorized users in the airspace
  - DHS use cases
    - Border patrol operations planning, scheduling, and monitoring (Air Marine Operations Center)
    - Protection of VIP personnel
  - FAA Reauthorization Requirements (Section 2208- UTM and 2209 – dynamically restricting operations)
- International interest: JAXA, S. Korea, France, UK, New Zealand, Australia, Sweden, Italy, Canada, and others
- Global UTM Association is formed

NuSTAR: Performance Benchmarking for sUAS

- Performance benchmarking: responsible, credible, collaborative (move towards self-certification)
- National UAS Standardized Testing and Rating (NuSTAR)
- Parallel: Underwriter's Laboratory, Consumer Reports, JD Powers, Which?
- Credible test bed and scenarios
  - Drop tests
  - Urban, rural, atmospheric conditions (e.g., fog, smog, rain)
  - Simulated pets
  - Failure modes
  - Sub-system level performance: engine/propulsion, networking, battery, sensor systems, software systems
  - Cyber-security, GPS denied conditions, etc.
- Support UAS manufacturers, consumers, insurance companies, and public at large through objective assessments for self-certification to meet FAA requirements
- Forensics analysis: Re-creation of incidents and accidents

Beyond NextGen

- UTM is a small step towards safely enabling UAS operations
- Construct of operator, service supplier, and regulator is defining the infrastructure – allows to accelerate innovation and scalability
- Research: Will the UTM kind of construct migrate to entire airspace operations?

Summary

- Research Transition Team with FAA, DHS, NOAA, DOI, and DoD
- 200+ industry and academia collaborators and increasing
- Initial UTM Concept of Operations: Industry, academia, and government
- Technical Capability Level 1 with 12 partners completed
- Technical Capability Level 2 in October 2016
- National Campaign with FAA Test Sites successful completed on April 19 2016
- UTM Weather Workshop in July 2016
- Established several working groups to help develop the concept
- International interest

Back UP

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Protecting key assets

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Scalable Operations for Economic Growth

Ever-increasing applications of UAS: Commercial, Agricultural, and Personal

NASA Deliverables

- Airspace Operations Performance
  - Concept of operations
  - Information architecture
    - Data and information needs (e.g., constraints)
    - Data exchanges among operators
    - Data exchanges with ATM
    - Interfaces
  - Roles and responsibilities among UAS operator, UAS Service Suppliers (USS), and Regulator
  - Performance requirements

UAS Traffic Management

In close collaboration with the FAA, industry, and academia

- 2.6M commercial small UAS are expected by 2020: Need a way to manage beyond visual line of sight UAS operations in the low-altitude airspace
- UTM is an instantiation of air/ground integrated increasingly autonomous system – in lower and/or uncontrolled airspace
- Cloud-based, connected, federated system
  - Flexibility where possible, structure where necessary
  - Risk and performance based
- Defined roles/responsibilities: UAS operator, UAS support service supplier, and regulator (implications on who pays)